

SUMMARY OF WORK PERFORMED UNDER

BELLCOMM/NASA TASK 11

January 31, 1964

Bellcomm, Inc.
Washington, D. C.

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1.0 Introduction

This document presents a brief summary of the work carried out under Task Order Number 11 of Contract NASw-417.* The purpose of these studies is to evaluate the natural environmental factors, and associated environmental programs, of importance to the successful performance of the Manned Space Flight Program. Consequently this document will consider the work carried out in two sections corresponding to studies of the space environment and of the relevant flight programs. Most of the studies to be discussed have been presented in detail in interim, or final, reports and a list of these documents is attached as Appendix II.

* A copy of Task Order Number 11 is attached to this document as Appendix I.

2.0 Environmental Studies

2.1 Lunar Surface Properties: The objective of the studies has been to obtain an estimate of the hazard offered by the lunar surface to a lunar spacecraft. The studies have been of two kinds: first, a general critical review of the environmental and theoretical information concerning the characteristics of the lunar surface, with particular attention to the small-scale topography of the marial regions, and second, detailed studies.

The general studies have led to the statement of a nominal model⁽¹⁾ of the characteristics of the lunar surface. This model in turn led to the conclusion that marial surfaces offer the least hazard for an initial lunar landing but that so little is known about small-scale topography, surface texture, and bearing strength that estimates of these factors must be based in part on analogy with terrestrial features. An extension of this work⁽²⁾ discussed the arguments concerning the small-scale topography and concluded that the debate between a "rough" and "smooth" surface could not be resolved.

To investigate this problem further a detailed study was made of the information obtained from lunar radar studies.⁽³⁾ It was shown that the assumptions necessary to make calculations concerning topography on the basis of the radar signal returned from the moon are sufficiently uncertain as to leave the numerical values obtained in some doubt.

An analysis was made of the effect of meteoric infall on the roughness of the lunar surface⁽⁴⁾ which led to a considerably "rougher" model for the lunar surface than that indicated by lunar radar data. This analysis indicated the possibility of a severe hazard to a landing spacecraft due to large fragments ejected from meteoritic craters. However, since processes other than meteoritic infall could be important in determining lunar topography the results of the analysis must be treated with caution.

An extensive study was made of the photometry and polarimetry of the moon⁽⁵⁾ with particular reference to their relationship to the physical properties of the lunar surface. It was concluded that the lunar surface is covered, to at least millimeter depths, with an intricate matrix of small adhesive grains. It was recommended that serious attempts be made to simulate such a surface matrix to enable accurate simulation of lunar lighting conditions.

A study of lunar soil mechanics⁽⁶⁾ indicated the unreliability of present estimates of these properties and the critical importance of experiments performed in situ by the unmanned lunar program so that reasonable estimates of bearing strength can be made.

2.2 Radiation Environment: Two aspects of the radiation environment have been considered in detail, radiation flux due to trapped particles in the natural and artificially induced belts surrounding

the earth and that due to cosmic rays resulting from solar flares. The results of these studies are presented in three reports.^(7,8,9)

Environmental data and theoretical considerations concerning the trapped belts have been critically reviewed and models for both proton and electron fluxes have been proposed.⁽⁹⁾ During this review it was indicated that the characteristics of the radiation belts would be better defined if data from various earth orbiting satellites could be assembled and evaluated. A report⁽⁷⁾ was issued recommending that OMSF encourage the appropriate NASA office to place emphasis on this activity. A computer program has been compiled to compute the geomagnetically trapped radiation intercepted by spacecraft either in earth orbit or on translunar trajectory. Data from both Telstar and Explorer XV were utilized in compiling this program. Several interesting results⁽⁸⁾ have been obtained from applications of this program.

A similar study was performed on the information concerning solar cosmic ray events⁽⁹⁾ leading to a model of the temporal and energetic characteristics of such events and estimates of the probability of encountering an event during a given mission as a function of the size of the event. Calculations have been performed concerning the skin dose received by an astronaut inside the Apollo Command Module due to encounter with a solar cosmic ray event.

The calculations have required close monitoring of the shielding provided by the Command Module and recommendations have been made concerning means to improve the effectiveness of the shielding.⁽⁸⁾

Possible abort procedures from the lunar surface in the event of a solar flare have been analyzed. A preferred procedure has been described.⁽⁸⁾ During this analysis it was recognized that differences between the solar flare proton model used in the calculations and that derived by MSC were critical. It was recommended that further study be made of the smaller solar flares, and their detection techniques, which led to this discrepancy.

2.3 Meteoroid Environment: Studies have been made concerning the experimental and analytical techniques used to characterize visual and radar meteors. Similar studies have been performed for the micrometeoroid experiments flown on various earth orbiting satellites and space probes using both microphone and penetration techniques. A critical review has been made of the information concerning hypervelocity impact phenomena. The resulting information has been combined to obtain a model⁽¹⁰⁾ of the penetration hazard offered to a spacecraft.

Particular attention has been paid to the direct penetration data obtained by Explorer XVI, close liaison being maintained through

participation on the OART-NASA Meteoroid Working Group. Through the medium of this working group the forthcoming Saturn Meteoroid Experiment has been monitored and suggestions for future meteoroid experiments have been made.

A particular study was performed on the hazard offered to both the Lunar Excursion Module and an astronaut on the lunar surface due to secondary meteoroids (ejecta resulting from primary impacts on the lunar surface.) A report⁽¹¹⁾ was completed showing that such a hazard is not appreciably greater than the hazard from the primary meteoroid influxes.

As reported earlier, the results of these studies were utilized to determine the effect of meteoric infall on lunar surface topography.

2.4 General Activities: As part of Task 11, the responsibility was assigned to Bellcomm for two OMSF documents. OMSF requirements for data concerning the natural environment were revised and Issue III of the formal document "Requirements for Data in Support of Project Apollo" was prepared. Relevant studies and information exchanges were made leading to revisions and modifications of OMSF Program Directive, "Natural Environment and Physical Standards for Project Apollo."

As a further part of Task 11, participation in a large number of more general system engineering activities has taken place to

ensure adequate consideration of environmental factors. Included in these have been particular efforts concerning spacecraft landing dynamics,⁽¹²⁾ system constraints on the location and number of lunar landing sites⁽¹³⁾ and terminal phases of Lunar Excursion Module descent to the lunar surface.

All phases of these environmental studies have involved a large number of interactions with various NASA organizations and the scientific community at-large.

3.0 The Unmanned Program

Bellcomm studies of the Unmanned Program were included in Task 11 on October 10, 1963. To preserve continuity, this report will cover activities from January 31, 1963.

3.1 Lunar Unmanned Program Review: The Lunar Unmanned Program was reviewed from the point of view of Apollo Support. It was concluded that the program with appropriate readjustments had the capability of Apollo Site Selection.

Briefings were prepared and presented to Drs. J. F. Shea, D. B. Holmes and G. E. Mueller through the year and to the President's Scientific Advisory Committee on June 19, 1963.⁽¹⁴⁾

These briefings discussed a strategy of lunar site certification which required Orbiters and Surveyors to complement each other as well as discussing the capabilities of each program and ways in which they could be optimized.

3.2 Ranger: A review of Ranger 6-9 television system was held at JPL on 3/1/63 in order that OMSF and Bellcomm could be brought up to date on the recent changes in the system. An analysis of the quality of the expected Ranger pictures was carried out and found to be in fairly close agreement with that made by the Ranger Project itself. Our results were passed on informally to the JPL project manager on a later visit.

3.3 Surveyor: Numerous reviews of the Surveyor system have been attended and informal suggestions have been passed on to the program manager. In analyzing the capabilities of Surveyor S1-7, we have been able to make a number of suggestions which could be incorporated into follow-on Surveyors to increase their capability in the area of Apollo site survey.

We have formally participated with the Office of Space Sciences in reviews of the soil mechanics experiments for Surveyors 1-7 and in the studies still in progress for the Follow-on Surveyors. In particular we have joined JPL in preparing the work-statement for the Surveyor Light-Weight Roving Vehicle (SLRV) and have attended all reviews of the work of their sub-contractor. We are currently providing a representative for OMSF on the SLRV experimenter panel who has the responsibility of interpreting Apollo site certification criteria.

We are participating in a Follow-on Surveyor Payload study with a representative on the Ad Hoc Committee set up by the OSSA. (15, 16, 17, 18)

3.4 Orbiter: Since August 1962 we have provided consultants to the OSS for their initial planning of the present Lunar Orbiter Project. We attended all the reviews of their study contractor, STL, and passed on to OSS appropriate informal recommendations for their consideration

which arose out of our studies, e.g. radiation effects on film due to the Van Allen Belts and Solar Proton Cosmic Ray events.*

When Langley Research Center was assigned the project management of the Lunar Orbiter Program, we informally briefed them on our studies and prepared sections dealing with photographic requirements.

During our investigation of the Orbiter a number of reports were written, some of which we released for general issue.^(19,20,21) The others, in the form of internal memoranda, were passed on informally to the appropriate members of the OSS and Langley Research Center.

3.5 Site Survey Strategy and Statistics: During our studies of the Lunar Unmanned Program we have developed a strategy of site certification and a statistical analysis which can be used to evaluate the effectiveness of a particular experiment as well as the effectiveness of the program as a whole. An early report⁽²³⁾ introduced the strategy and the initial concepts of statistical analysis while a companion report expounds on the analysis.⁽¹⁶⁾ Much of the work described in these reports is applicable to the Lunar Reconnaissance Module concept.

* This work has since been extended and will be reported.⁽¹⁹⁾

3.6 Particles and Fields Programs: A review of the OSS's programs in the area of energetic particle radiation in the Van Allen Belts and from the sun was carried out and is reported in a companion paper.⁽²²⁾

4.0 Conclusion

This document has presented a brief summary of the studies performed under Task Order Number 11 of Contract NASw-417. The work has consisted of studies aimed at defining models of the environmental factors of importance to the Apollo program. Particular attention has been paid to the lunar surface and the meteoroid and radiation environments. Proposals have been generated as to ways in which the uncertainties surrounding these factors could be reduced.

In addition, detailed evaluations have been made of the relevant unmanned flight programs with particular attention to the lunar program. An analysis has been performed of the uses of the unmanned lunar program to select and certify a landing site for the Apollo program. Many suggestions have been made concerning the optimization of the potential support offered by the unmanned lunar program.

In conclusion it should be stressed that all the work which has been discussed should not be considered to be definitive, in part because knowledge of the space environment is incomplete and in part because of the changing status of the program.

BTH
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REFERENCES

1. Lunar Surface Characteristics, R. F. Fudali, Revised June 25, 1963.
2. Small-Scale Lunar Topography, R. F. Fudali, June 28, 1963.
3. Lunar Radar Studies, W. B. Thompson, June 30, 1963.
4. Meteoric Infall and Lunar Surface Roughness, G. T. Orrok, January 31, 1964.
5. Photometry and Polarimetry of the Moon and Their Relationship to Physical Properties of the Lunar Surface, C. A. Pearse, August 23, 1963.
6. Lunar Soil Mechanics, N. W. Hinnners, January 13, 1964.
7. Recommendations for Data Collection and Analysis of Trapped Radiation Belts, H. J. Schulte, June 17, 1963.
8. The Radiation Environment of Apollo - Interim Report, D. B. James, M. A. Leibowitz, H. J. Schulte, October 21, 1963.
9. Models for Space Environmental Hazards: Radiation - Issue II, H. J. Schulte, E. N. Shipley, January 31, 1964.
10. The Meteoroid Environment of Project Apollo - Edition II, G. T. Orrok, January 31, 1964.
11. Penetration of Spacecraft by Lunar Secondary Meteoroids, W. S. Boyle, G. T. Orrok, June 28, 1964.
12. Lunar Landing Site Constraints, W. B. Thompson, January 31, 1964.
13. Lunar Landing Dynamics, T. L. Powers, September 13, 1963.
14. Unmanned Support of Project Apollo (slides of an oral presentation to PSAC), B. T. Howard, D. B. James, June 19, 1963.
15. Surveyor Site Certification Study, H. W. Radin, January 31, 1964.
16. An Analysis of Lunar Site Survey by the Unmanned Program, C. J. Byrne, R. F. Fudali, M. A. Leibowitz, T. L. Powers, January 31, 1964.
17. Draft to be incorporated in "Surveyor Follow-On Study - Scientific Objectives - Phase II," February 1964.

18. Statistical Decision and Lunar Site Certification, M. A. Leibowitz,
December 31, 1963.
19. Lunar Photographic Spacecraft: Radiation Considerations, H. J. Schulte,
in preparation.
20. Lunar Photographic Orbiter: General Description, D. B. James,
June 30, 1963.
21. Lunar Photographic Orbiter: Lighting and Viewing Conditions, C. J. Byrne,
October 11, 1963.
22. Status of Programs to Measure Solar Cosmic Rays, E. N. Shipley,
January 31, 1964.
23. An Operations Research Study of a Strategy for Locating Lunar Landing Sites,
T. L. Powers, B. T. Howard, R. F. Fudali, March 14, 1963.

APPENDIX I

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON 25, D. C.

Date October 10, 1963

To: Bellcomm, Inc.
1100 17th Street, N.W.
Washington 6, D. C.

Attention: Dr. J. A. Hornbeck

1. This letter constitutes Amendment No. 1 to Task Order Number 11 under Contract NASw-417. This amendment, upon acceptance, becomes a part of the contract between NASA and Bellcomm, Inc.

2. Attachment 1 hereto amends the detailed description of the work to be performed. Upon completion, you shall submit in accordance with contractual requirements:

- ☒ A Technical report of the work completed
☐ A Certificate of completion

3. Attachment 2 amends the special instructions regarding technical reporting and milestone requirements applicable to this task order.

4. The following revised estimates of the time and effort required to perform this task order have been developed in conjunction with your staff and are hereby authorized:

Estimated Man-months: This Amendment 15; Revised Total 65

Estimated Completion Date: January 31, 1964

Joseph F. Shea
Technical Coordinator

Dr. Joseph F. Shea
Office of Manned Space Flight

Authorized W. M. Collins, Jr.
Contracting Officer

Contractor Endorsement

Date Oct. 11, 1963

To: NASA Headquarters
Attention: NASA Contracting Officer

Task Order No. 11, as amended, is accepted.

Task Manager B. T. Howard

By J. A. Hornbeck
Bellcomm, Inc.

Case 211

ATTACHMENT 1

TECHNICAL DESCRIPTION OF WORK UNDER
TASK ORDER NO. 11, AMENDMENT 1

TITLE: To carry out a study leading to the evaluation of the natural environment factors, and associated experimental programs, important to the successful performance of the Manned Space Flight Program.

REQUIREMENTS: The objectives of the study are:

- (1) To gather available information concerning these factors in order to optimize the performance of the Manned Space Flight Program.
- (2) To prepare engineering design models of these factors on the basis of existing information and revise existing models as further information is made available.
- (3) To evaluate the usefulness of relevant experimental programs, approved or proposed, in reducing the uncertainties in knowledge of these factors.
- (4) To evaluate the support offered by the unmanned lunar program consisting of the Ranger, Surveyor, and Orbiter programs.
- (5) To generate proposals concerning the development and operations of the Ranger, Surveyor, and Orbiter programs which will lead to the maximization of the support offered to the Apollo program.
- (6) To generate proposals for methods by which further necessary information concerning these factors may be obtained either by modification of existing programs or by initiation of new programs.

ATTACHMENT 2

REPORTING REQUIREMENTS
TASK ORDER NO. 11, AMENDMENT 1TECHNICAL REPORTING REQUIREMENTS

1. A final report will be submitted to OMSF by January 31, 1964.
2. Important results and recommendations will be reported as obtained.

MILESTONE REPORTING REQUIREMENTS

None

FINANCIAL REPORTING REQUIREMENTS

A monthly financial report shall be submitted for this task on NASA Form 533 in accordance with the procedures set forth in NASA letter dated July 3, 1962, Subject: Reporting Requirements for Contract NASw-417; and NASA letter dated August 23, 1962, Subject: Manpower Reporting Requirements for Contract NASw-417.

APPENDIX II

Reports Submitted Under Task Order No. 11

1. Lunar Surface Characteristics, R. F. Fudali, Revised June 25, 1963.
2. Small-Scale Lunar Topography, R. F. Fudali, June 28, 1963.
3. Lunar Radar Studies, W. B. Thompson, June 30, 1963.
4. Meteoric Infall and Lunar Surface Roughness, G. T. Orrok, January 31, 1964.
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